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Sound producing insects with loud, continuous calling songs cease singing at the approach of an intruder. These naturally occurring insects may, therefore, be used as sensors of enemy infiltrators. Sound levels, calling distances, approach distances, singing restart times, and density surveys were made on ten commonly occurring species of sound producing insects found in southeastern United States and Panama. Briefings with ten DOD groups indicate the need for training in the use of these insect sensors.

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OFFICE OF NAVAL RESEARCH

Contract #N00014-80-C-0829

Task No. NR 139-004

FINAL REPORT

Indigenous Acoustic Detection

by

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January 1982

[redacted]

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Introduction

The idea of using sound producing insects as sensors stemmed from 13 years of field research on these insects and their calling songs. Collecting singing insects was difficult because most sing at night and, therefore, must be located by their sound. The problem is compounded because the insect usually detects my presence and ceases singing before capture. The sensory ability of insects became obvious when my partner and I separated in the field. I often located him, and likewise, he located me by the cessation of insect sounds near us. I received further support from Army and Marine Corps officers and NCO's, most of whom had served in Viet Nam and had used or demonstrated the need for research on sound producing insects as sensors in the jungle.

After completing the original research on the feasibility of using sound producing insects as sensors, I was asked to interview various DOD units to determine if they had a need for training on the use of sound insects in their particular area of the service. A summary of these suggestions from the ten DOD units visited is given in the Appendix. The results of the original research on the feasibility of using sound insects as sensors follow.

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Sound Producing Insects as Sensors
Results

The fact that insects may be used as an indicator of human presence is shown in table 1 which compares sound level, calling distance, approach distances, and singing restart times for 10 common sound producing insects in southeastern US found near or on the ground. The insects were approached with an average gait until the song ceased. The singer's approximate distance was calculated by triangulation and then recorded. Calling song intensity was measured with a portable DB meter at 1 m. All 10 species had loud, continuous calling songs that would cease at the approach of an intruder.

Since all readings were made under natural field conditions, sample standard deviation readings are typically high. Variations in sound level readings are most likely due to obstructions such as vegetation or stones that may be blocking the sound. Many of the cricket sound level readings were taken when the insects were under grass or leaves. Likewise calling distance readings (distance that I could hear the insect with my unaided ear) were dependent on such factors as physical obstructions, humidity, background noise, and frequency of the insect sound. Anurogryllus muticus sang in a parabolic depression (Walker, Whitesell, and Forrest, 1981) that reflected the sound upward which gave a low calling distance reading at ground level yet a high 1 m DB reading that was taken over the parabolic depression.

Frequency differences in insect calling songs resulted in much discrepancy between sound level and distance readings. Lea floridensis has a relatively low mean DB reading, but due to its low carrier frequency, I can hear it a greater distance than some of the louder high frequency Neoconocephalus species (table 1). Differences in frequency hearing ability of the observer is also an important factor in calling distance measurements. N. retusus has a high frequency whine that I could only hear for an average of 60.9 m. My assistant who is twenty years younger heard N. retusus 20 percent farther than I and heard some conocephaline katydids that I never heard at any distance. The greatest calling distance was 400 m heard by me and several Marines at Camp Lejeune. The katydid was N. robustus and the conditions were ideal.

The approach distances, determined with a average gait, varied both interspecifically and intraspecifically. Oecanthus species would occasionally sing while I was shaking their perch; however, most of the sound producing insects are difficult to approach and more difficult to spot visually and catch. N. caudellianus is one of the latter species. Its behavior of synchronizing with near by conspecific males may actually confuse the predator as to the location of any one individual. L. floridensis specimens were all found in palmetto plants whose leaves rustled loudly as one disturbed them while approaching. The only close approaches were made when the palmetto plants were sparse so that the singer could be located without disturbing the plants. Other intraspecific variation was due to variations in light intensity and

dryness of the leaf litter under foot. Neoconocephalus species in open areas were all hard to approach under full moon conditions. The A. muticus near building lights usually stopped singing if the observer cast his shadow over the insect; likewise, they usually stop singing when a flashlight was shown on them. Approaches on dry leaf litter were much more difficult than approaches on damp leaf litter. The probable differences are the ultrasonic sounds made by the foot falls when the litter is dry. These sounds can be readily heard using an ultrasonic detector (HRB - Singer, 1964; 1966).

Singing restart times (the time elapsed from cessation of song to song restart) were only checked for five species. Three Neoconocephalus species would not restart until after five minutes, at which time I stopped timing them. The N. caudellianus individuals restarted sooner; however, they were singing in synchrony. It seemed that neighboring synchronous singers, who continued singing, "turned on" those that had stopped. The other fast restarter was L. floridensis that seems so well protected in its thick saw palmetto habitat that selection probably does not favor long cessation of the calling song.

Oecanthus species had adequate calling songs but were not included in table 1 because cessation of song seldom occurred at the approach of an intruder; in fact, cessation often was accomplished only after actual contact with the insect or its perch. Also, when these insects were found, they were usually in a dense population resulting in overlapping calling songs. The latter phenomenon makes it difficult for the observer to locate the individual that stopped singing. Neoconcocephalus melanorhinus was the most abudant sound producer in the salt marshes from northern Florida to North Carolina and, like Oecanthus species, it had a loud continuous song but readily stopped singing at the approach of an intruder. Unfortunately, this species sang for only short periods during the evenings. The singers chorused for several minutes and then remained quiet for at least 10 minutes. One evening I observed this species from 2045-2230 hours with a total singing time of 11 minutes unlike the Anurogryllus muticus population that sang most of the night (Walker and Whitesell, 1981). Singing was more abundant during the hour before sunset. The N. melanorhinus is included in table 1 as a good sensor, but its usefulness is limited by the lack of total singing time.

In some cases the high population density is beneficial for locating intruders. Microcentrum retinerve and Pterophylla camelifolia are two arboreal katydids that produce most of the night time noise in eastern hardwood hammocks. Locating an individual for measurements in table 1 is not feasible because of overlapping calling songs and inaccessibility of the sound coming from overhead tree branches; however, my assistant, stationed in the understory, located my approach on five out of six attempts by noting the cessation of several of these overhead katydids. On the sixth approach he located me by a twig snap rather than by cessation of katydid songs. We described the effect as being much like a hole or void in the noise level over the location of the intruder. This effect was noticeable to the still observer - not to the moving

intruder. The closest approach that I was able to make in this thick hammock was 20 m. The insects were most effective in the dense vegetation where many sophisticated sensors would be useless.

A moving intruder can actually be followed when the insects are spaced along or near the ground. Along Georgia Rt. 94, a dirt road parallels the highway about 15 m away. The dirt road and intruder were hidden from the observer on the highway by vegetation. While acting as an intruder, I approached and passed my assistant standing on the highway without being seen, although as the insects along the way ceased singing, he told me my position by radio. A similar procedure was used in a demonstration for a representative from the Marine Corp Development Center, Quantico, Viriginia.

Singing Density Surveys

Several military officials understandably questioned if there were enough singing insects in a given area to make training on their use worthwhile. Driving and walking surveys were used to give an approximation of singing density. Driving surveys (table 2) were made while traveling at 35 mph with the car windows open. When a singer was heard, the species and odometer reading were called into a hand-held tape recorder. Driving surveys were beneficial since a large area could be surveyed in a short time; however, only singers close to the road could be heard due to wind noise and other background sounds made by the automobile.

Walking surveys (table 3), though slow, eliminated these problems. Readings made while walking were called into the hand-held tape recorder when the insect was approximately at right angles. The walking surveys in South Georgia were randomly chosen along state highway 94 between Valdosta and Fargo (southwest edge of the Okefenokee swamp).

The list of walking and driving surveys shown in tables 2 and 3 indicates the great abudance of sound producing insects in these areas. Surveys in hardwood or mixed hardwood/pine hammocks are not shown because of the difficulty in locating their exact positions in the overhead branches. Also, tables 2 and 3 contain no results in pine tree farms because the singers were sparse to non-existant. The lack of singing insects in the massive pine monoculture remains a mystery.

Katydids and crickets were abundant in study areas in Georgia and Florida (tables 2 and 3). These great numbers did not exist in Panama. Although many katydid and cricket species exist in Panama, some of them good sensors, their density was low and they were not included in this study. The *A. muticus*, though abundant in jungle open areas, was rare in areas covered with canopy. This paucity of sound insects in dense jungles of the new world tropics has been observed by Walker (1981) in other Caribbean studies, but, Lloyd (1981) and others (especially Viet Nam veterans) claim that the old world tropics have an abundance of sound producing insects. The lack of sound producing insects in the new world tropics may be explained by the recent discovery of a bat species in Panama that preys on these insects by using sound location. Unfortunately, the Panama study was limited to 10 days at one location and was not a fair sampling of year round singing activity. While driving from the airport on the dryer Pacific side, we heard many *Neoconocephalus affinus*, but we were unable to make accurate density counts.

Driving and walking surveys in South Georgia indicated that the greatest abundance of singing occurred in mid-July (table 2 and 3) although some singing can be heard any night during the year when the temperature is near or above 15°C; in fact, the winter generation of *N. triops* is noted for its high singing density during warm winter nights in the southeast (Whitesell, 1978).

When one considers density/mile (tables 2 and 3) with calling distance and approach distance (table 1), the evidence indicates that these insects are numerous and sensitive enough to be considered worthwhile sensors in all areas studied except pine tree farms and canopy covered jungle in Panama.

Discussion

The main advantage of using sound producing insects to locate the enemy is based on the simple notion that, "they are there - use them." They can be heard by the "trained" human ear, especially personnel under 30 who have not lost their upper frequency hearing. The research clearly indicated that the singing insects are abundant, they can be heard for considerable distances, and they act as good sensors of human presence. Though singing insects are ubiquitous in warm areas, even in the desert (Nevo and Blondheim, 1972; Shulov, 1969), they do not sing in temperatures below about 15°C and most do not sing in daylight. The point remains, when "they are there - use them." They have no equipment failures, no supply problems, and cost nothing.

Military personnel have suggested several situations where sound producing insects can be used. Some ideas are base security operations, in an observation post, security halts on recon operations, and search and destroy operations. The applications are immense, but useless unless the personnel are aware of the application of sound producing insects as sensors.

Awareness training is essential for all personnel, even for those who have lived in rural settings with insect sounds. These people usually habituate to individual insect sounds as background noise and only respond to a sudden complete silence.

Recommendations for training and further research were made by ten DOD groups that I visited (see Appendix). All groups at least recommended an awareness film and most wanted some form of on-the-spot training as was given to 12 Recon Marines at Camp Lejeune, North Carolina. Once briefed, these men were able to hear and locate insect sounds in the field. Further training modes including use of artificial crickets that could be used regardless of weather conditions were suggested by some groups. Training methods and continued research on sound insects (including those found in the old world deserts) are considered in a renewal proposal sent to ONR.

The author hopes that ground based troops will be made aware of the use of sound insects by one or more training modes. As one Army Ranger Colonel stated in response to the use of sound producing insects, "Every soldier needs this awareness training which has many critical applications."

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*Publications from current contract

Table 1

Summary of Sensory Characteristics of Ten Insects Considered Good Sensors

Genus and Species	Sound Level at 1m (DB)			Calling Distance (m)			Approach Distance (m)			Singing Restart Time (minutes)		
	n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s
A. muticus	9	87.5	2.0	7	73.3	20.2	8	2.6	1.6	-	-	-
G. firmus	7	70.0	4.3	6	32.8	7.5	6	5.0	1.4	-	-	-
G. rubens	5	70.0	5.1	6	32.6	4.7	6	4.5	2.2	-	-	-
Lea floridensis	2	63.0	1.4	5	155.0	7.9	7	6.7	3.0	8	.4	.5
N. caudellianus	5	87.0	1.6	11	152.7	36.4	11	9.8	6.9	6	.3	.1
N. melanorhinus	5	78.6	1.9	9	36.4	6.4	9	5.3	0.9	9	>5.0	-
N. retusus	-	-	-	7	60.9	10.5	6	6.1	3.2	6	>5.0	-
N. triops	8	83.5	4.4	17	92.1	25.8	15	5.0	1.5	-	-	-
N. robustus	5	88.4	1.1	5	220.0	133.9	5	5.4	2.7	5	>5.0	-
N. velox	3	85.3	1.5	8	109.1	15.1	8	7.2	2.9	-	-	-

Table 2

Driving Surveys of Sound Producing Insects
Considered Good Sensors

Location	Time	Date	Distance	Habitat	Number Heard	Density/ mile	Genus and Species
GA Rt. 94	0010-0120	27 June 1980	11.0 miles	shrubs and grass	42	3.8	*N. caudellianus* *N. velox*
GA Rt. 94	2215-2300	1 July 1980	9.6 miles	shrubs and grass	207	21.6	*N. caudellianus* *N. velox* *G. rubens* *G. firmus*
GA Rt. 94	2300-0100	15 July 1980	12.7 miles	shrubs and grass	710	29.9	*N. caudellianus*
GA Rt. 94	0025-0200	1 Aug. 1980	38.1 miles	shrubs and grass	195*	5.1	*N. caudellianus*
Ft. Sherman**	2015-2030	8 Dec. 1980	2.4 miles	jungle trail	28	11.7	*A. muticus*
Ft. Sherman	-	8 Dec. 1980	2.0 miles	open area	39	19.5	*A. muticus*
Ft. Sheramn	2040-2055	13 Dec. 1980	2.5 miles	jungle trail	9*	3.6	*A. muticus*
Ft. Sherman	2100-2110	13 Dec. 1980	2.0 miles	open area	30	15.0	*A. muticus*
Ft. Sherman	2045-2055	14 Dec. 1980	1.2 miles	open area	26	21.7	*A. muticus*
Ft. Sherman	2100-2110	14 Dec. 1980	2.0 miles	open area	50	25.0	*A. muticus*
Ft. Sherman	2125-2136	14 Dec. 1980	2.5 miles	jungle trail	24	9.6	*A. muticus*
Ft. Sherman	1930-1939	15 Dec. 1980	1.8 miles	jungle trail	4	2.2	*A. muticus*
Ft. Sherman	2219-2227	15 Dec. 1980	2.8 miles	open area	27	9.6	*A. muticus*
Ft. Sherman	2229-2231	15 Dec. 1980	0.2 miles	open area	15	75.0	*A. muticus*

*Poor singing conditions during the survey, i.e., rain, wind, or low temperature
**Ft. Sherman (US Army Jungle Operations Training Center, Republic of Panama)

Table 3

Walking Surveys of Sound Producing Insects
Considered Good Sensors

Location	Time	Date	Distance	Habitat	Number Heard	Density/ mile	Genus and Species
GA Rt. 94	2147-2718	26 June 1980	400 m	shrubs and grass	12	48.0	_N. velox_
GA Rt. 94	2224-2254	30 June 1980	400 m	shrubs and grass	14	48.0	_N. velox_ _N. caudellianus_ _G. rubens_
GA Rt. 94	2309-2325	30 June 1980	400 m	shrubs and grass	16	64.0	_N. velox_ _N. caudellianus_ _G. rubens_
Jupiter, FL	2100-2115	11 July 1980	400 m	Palmetto flatwoods	19	76.0	_L. floridensis_
Jupiter, FL	2130-2200	18 July 1980	400 m	Palmetto flatwoods	5*	20.0	_L. floridensis_
GA Rt. 94	2225-2245	14 July 1980	400 m	shrubs and grass	16	64.0	_N. velox_ _N. caudellianus_ _N. triops_
GA Rt. 94	2325-2340	14 July 1980	400 m	shrubs and grass	24	96.0	_N. velox_ _N. caudellianus_ _G. rubens_
GA Rt. 94	2345-2400	14 July 1980	400 m	shrubs and grass	31	124.0	_N. velox_ _N. caudellianus_ _G. rubens_
Ft. Sherman**	1900-1930	10 Dec. 1980	580 m	jungle path	14	38.6	_A. muticus_
Ft. Sherman	1903-2015	13 Dec. 1980	1340 m	jungle path	14	16.7	_A. muticus_

*Poor singing conditions during the survey, i.e., rain, wind, or low temperature
**Ft. Sherman (US Army Jungle Operations Training Center, Republic of Panama)

Appendix
(Summary of Travel Results)

On 4 September 1980, Mr. J. F. Van Sant (Chief, Intel. Bran., IEW Dr. ODCSCD, TRADOC, Fort Monroe) met with Dr. F. Santana (Project Director, ONR), Major W. Fox and Captain D. Weber (Marine Development Center), Mr. Rod Dana (Army Security, Fort Belvoir), and me at Quantico Marine Base Development Center. Mr. Van Sant indicated that the Army had conducted classified studies to develop a garrison defense system utilizing sophisticated electronics and animal behavior (HRB - Singer, 1964, 1966). Although the study was not designed for the mobile soldier, it indicated the feasibility of insects as intruder sensors. The conclusion of the conference was that both Army evidence and my evidence demonstrate the feasibility of sound producing insects as sensors of enemy infiltration.

The project was therefore directed to discover the need of insect sensors in various branches of the Armed Services. If the need existed, how could the insects be best used to suit the needs of the particular service group, and what type of training would the men need? In order to answer these questions, I visited the following groups where I held briefings, demonstrations (if weather permitted), and conducted question and answer sessions:

A. Camp Lejeune, North Carolina (C Company, 2d Recon Bn)
24-27 August 1980

I learned the purposes and methods of reconnaissance operations. Twelve enlisted men under the direction of Sgt. E. E. Lugo were tested for their ability to hear and locate six common species with loud calling songs. All men could hear and locate these six common species, and all except two could hear the faint, high frequency song of *Cenocephalus fasciatus*, while everyone could hear and locate *Neoconcephalus robustus* at a distance of about 400 m.

Captain D. Iverson (C Company, Commanding Officer) recommended the use of sound producing insects as sensors during security halts, harboring, and while on an observation post. He also recommended training on the use of sound producing insects by way of training films, MCI courses, and field manuals.

B. Fort Sherman, Panama. Jungle Operations Training Center, (JOTC), 8-18 December 1980

Research was conducted in the jungle and surrounding areas by the consultant, Dr. T. J. Walker, and me. I also gave three briefings to Ltc. Ray Newman (Commandant), Major Carl Vencill, Cpt. Bruce Newman (Director of Training), and 45-50 training NCO's.

The officers at Fort Sherman recommended training films and on-the-spot training of the NCO's regarding use of insect sound. This last point was emphasized as the only way to do the job correctly. One officer strongly recommended the use of caged crickets to be placed on the perimeter.

C. Ranger Headquarters, Fort Benning, Georgia
16 January 1981

Attending: Colonel Duane Cameron (Director), Major Bill Potter (OPS Officer), and Major Greg Elliot (Chief, BRD). Recommendations include use of caged, indigenous crickets placed on the perimeter in the evening and removed the following morning. A training film and on-the-spot training would also be desirable.

D. Maxwell Air Force Base (ACSC), Montgomery, Alabama
17 January 1981

I talked with Major Larry Hoff, Air Force Special Operations, who recommended that all land-based operations should have access to insect sound training.

E. USAIMA. Army Special Forces, Fort Bragg, North Carolina
19 March 1981

Attending: Sixteen officers and enlisted men in Army Special Forces, including representatives from the Survival, Evasion, Resistance, and Escape (SERE) course.

Suggestions were made for awareness training using tapes and/or films and on-the-spot training. Insect sensor training would be particularly beneficial for SERE personnel. Also, suggestions were made to conduct research on the feasibility of seeding an area with reared crickets and cataloguing useful insect sounds in different world-wide locations - especially potential crisis areas.

F. Naval Special Warfare Group Two, NAB, Little Creek, Virginia
20 March 1981

Attending: Commanding Officer, Captain Ted Lyons, Commander L. Boink, and approximately 30 other representatives from Navy Seal and UDT groups.

Training on insect sensors was recommended in the form of slide/tape systems, video tapes, and "electronic training trails." The latter would consist of electronic insect sounds that would be turned off as the student approached the sound. Training of "Sound Insect Specialists" was also considered. It was emphasized that training in the use of sound insects would be particularly productive on a benefit-cost analysis.

G. Intelligence Branch, Army Training and Doctrine Command
Fort Monroe, Virginia 20 March 1981

Attending: Mr. John Van Sant, Chief, Intel. Br. IEW, Ltc. Phillips, ATCD-IR, Ltc. Karalekas, Major Thomas, Major Wright, Cpt. Anklin, Sgt. Jackson, Mr. Edmiston, and Mr. O'Keefe.

This group considered the value of training on insect sensors and also considered some of the problems of training the average infantry soldier. Suggestions were to make training films and to build an electronic training system that might be housed in a building. "Hands-on" training should be conducted first with high school students and then with military personnel. Another possibility was to train "Insect Specialists."

Recommendations for further research consisted of cataloguing insect sounds in different areas of the world (including the desert) and seeding of sound producing insects in a particular area. It was also recommended that I contact US Army Infantry Training Schools at Fort Sam Houston and Fort Benning.

H. Captain Maynard Weyers, Naval Special Warfare Representative, Pentagon, Washington, D.C. 23 March 1981

Captain Weyers recommended an awareness training film on insect sensors and development of caged cricket sensors placed along trails.

I. Joint Special Operations Support Element (JSOSE). Captain Tom N. Tarbox, Commanding Officer, MacDill Air Force Base, Tampa, Florida
3 April 1981

Attending: About twelve members of the JSOSE group, consisting of personnel from Navy Seals, Army Special Forces, and Air Force Special Operations. The following points were recommended:

1. Develop awareness films and/or tapes.

2. On-the-spot training - especially an electronic training system.

3. Catalogue useful insects in suspected critical areas, i.e., Central America, Persian Gulf area, Caribbean, and old world jungle.

4. Work with accessible natives that are suspected of using sound producing insects as sensors, i.e., the Negritos of the Philippine Islands and the Panamanian Indians.

5. Present findings and conduct research at the Jungle Survival Center, Naval Air Station, Cubi Point, Philippines.

6. Work with SERE group at Warner Springs, California.

7. Place caged crickets in a given area.

8. Release crickets in a given area.

9. Develop means to stop the cricket's song for purposes of tactical deception.